Industrial Materials For The Future

Project Fact Sheet

Development of Ultrananocrystalline Diamond (UNCD) Coatings

Benefits

- Developing the technological base to use UNCD thin films as low-friction corrosion- and wear-resistant coatings would enable optimizing energy efficiency in a wide range of mechanical systems.
- The development of UNCD-coated seals may result in a sixfold decrease in pump shaft frictional torque, which translates into a reduction of 80% in frictional energy loss.
- Significant energy efficiency improvement in the United States is anticipated.
- A particular application such as UNCD-coated seals for the production of more energy-efficient (up to 20% energy saving), cleaner, environmentally benign multipurpose mechanical pumps (for pumping fluid) is to be evaluated.

Applications

There are many rotating and/or sliding components in mechanical systems, such as shaft seals used in multipurpose pumps, bearings, and gears, that are critical to the operation of simple or complex systems in many IOF industries:

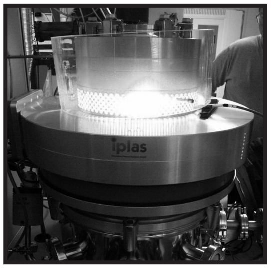
- **Agriculture,**
- **Aluminum,**
- **Chemical,**
- **Forest Products,**
- **Glass,**
- **Metalcasting,**
- **Mining,**
- **Petroleum,** and
- **Steel industries.**

Ultrananocrystalline diamond (UNCD) coatings on pump seals can impact all of the IOF industries

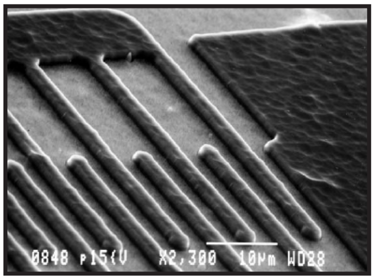
The objectives of this project are to (a) understand the fundamental processes involved in the growth of UNCD coatings, (b) develop a technological base for UNCD applications, and (c) demonstrate the applicability of UNCD coatings in industrial applications, such as multipurpose mechanical pump seals.

This materials development project, based on UNCD coatings that were conceived and patented at Argonne National Laboratory, will have a major impact on many of the Industries of the Future (IOFs). Prior work at Argonne demonstrated that UNCD coatings can be grown on a variety of substrates by using an emerging microwave plasma chemical vapor deposition technology. The UNCD coatings exhibit a unique microstructure that provides superior mechanical (high hardness), tribological (low coefficient of friction), chemical (inertness to chemical attack), and electronic (wide range of conductivity via doping) properties. In order to apply this technology to commercial applications, substantial work is needed on plasma physics and chemistry, diamond seeding processes on substrate surfaces, and film-growth processes to produce UNCD layers on large-area substrates with uniform thickness and microstructure. The project involves an interdisciplinary effort between Argonne, Floserve Corporation, and Northwestern University, which provides the fundamental, applied, and technological base for this project. As the scientific and technological base is developed for UNCD, applications will be identified and demonstrated for proof of concept. Further development of UNCD coatings for those applications would continue under separate projects.

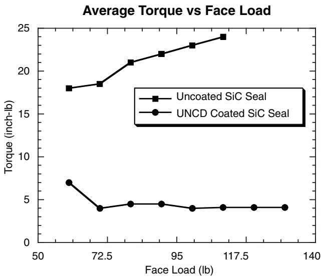
The first application identified for UNCD coatings is on seals in multipurpose mechanical pumps. In prior work, proof of concept of growing a UNCD coating using conventional microwave plasma technology has been demonstrated on a 2-inch seal, which showed an undetectable wear rate and a sixfold reduction in frictional energy loss in a bench-scale test. To produce larger seals in production quantities, proof of concept of growing UNCD coatings using an emerging microwave plasma reactor technology needs to be demonstrated.



Coating deposition system



UNCD etched through an Al mask by O_2 reactive-ion etching. The Al mask was removed chemically, leaving well-defined patterns of diamond on top of the SiO_2 layer.



Torque measurement as a function of load on uncoated and UNCD-coated SiC seals (both running against a SiC counterface).

Project Description

Goal: The goal of the project is to develop UNCD films for use as wear-resistant, low-friction coatings for SiC multipurpose mechanical pump seals. Such coatings will be important in all of the IOFs. A specific application, fluid pumping, has been identified to take advantage of the unique materials properties of UNCD films. High-velocity, possibly corrosive fluid pumping forms an important process step for many of the IOFs. While fluid pumping is emphasized in this project, it is important to note that the development of corrosive-resistant, wear-resistant, low-friction coatings will have a much broader useful impact.

Approach: Until recently, control of diamond microstructure was limited to affecting the crystal orientation (texturing) but not, in a significant way, the crystallite size. A major advance was achieved at Argonne National Laboratory recently, when it was discovered that diamond film microstructure can be controlled so that crystallite size spans the range from the micron to the nanometer size, a factor of a million in volume. The commercialization of UNCD-based seals will require development of microwave plasma chemical vapor deposition tools for growing high-quality, cost efficient UNCD coatings.

Issues: The proposed work will involve the following tasks:
– Basic and applied research to perfect a microwave plasma system for-large scale processing of seals, including development of a substrate holder with multi-seal handling, rotation, and heating capabilities.
– Development of in situ, real-time plasma diagnostic capability to control the UNCD growth processes for industrial-scale manufacturing of UNCD-based seals.
– Development of more technically advanced and cost-efficient diamond-seeding processes than those currently used for deposition of UNCD coatings.
– Optimization of the UNCD deposition process to produce large-area UNCD coatings with uniform thickness, microstructure, and properties suitable for high-efficiency seals.
– Characterization of the mechanical, chemical-stability, and tribological properties of the UNCD-coated seals, both in the laboratory environment and in industrial-scale tests.

Potential payoff: Developing the technological base to use UNCD thin films as low-friction, low-corrosion, and wear-resistant coatings is critical in order to optimize energy efficiency in a wide range of mechanical systems.

There are over 1.5 million pumps in service in the United States. By improving the reliability of sealing systems, there is considerable opportunity to improve energy efficiency, reduce spills associated with seal failures, reduce maintenance costs with their attendant losses in productivity, and improve environmental aspects.

The development of UNCD-coated seals may result in a sixfold decrease in the frictional torque of the pump shaft, which translates into a reduction of 80% in frictional energy losses. A particular application such as UNCD-coated seals for the production of more energy-efficient (up to 20% energy saving), cleaner, environmentally benign multipurpose mechanical pumps (fluid pumping) is to be evaluated. Significant energy efficiency improvement in the United States is anticipated.

Progress and Milestones

- R&D to identify appropriate plasma and substrate conditions for large-area UNCD deposition.
- Fundamental studies of surface seeding and UNCD growth processes.
- Small-scale seal testing.
- Pre- and post-test surface examination of candidate UNCD pump faces.
- Long-term industrial-scale characterization of seal performance testing and scale-up.
- Commercialization of the UNCD-coated seals.

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